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Woods Hole Oceanographic Institution



Short-Term Variability in Nighttime Scattering Strength Levels at One Site in the Eastern Algero-Provençal Basin

by

James A. Doult

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Technical Report



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Robert C. Spindel, Chairman
Department of Ocean Engineering

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by

James A. Douth

ABSTRACT

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SECRET

INTRODUCTION

A sequence of nine nighttime, broadband, volume scattering strength measurements collected in 1977 was used to study the variability of scattering strength in 100 Hz bands over frequencies ranging from 100 Hz to 24 kHz and depths ranging from 400 meters to 1000 meters. The original data measurement and processing techniques were presented by Stockhausen (1973), and the resulting volume scattering strength levels were presented by Douth (1977). The sound source, a 0.5 kg charge of TNT, was detonated at a nominal depth of 1800 meters. The receiver consisted of a 30-hydrophone end-fired array configured so as to produce an upward-looking beam (Figure 1). Signals from the array and several single hydrophones were amplified, bandpass filtered, digitized, and recorded. For the events considered here, the array was placed at a nominal depth of 1200 meters. The nine events, spanning a period of one hour and eleven minutes (see Appendix A), were originally taken to determine whether the measurement technique affected the results: i.e. whether the scatterers moved in response to the explosive charge used as a source.

Two of the five channels of the original data were used in the current study: the low-gain single-hydrophone channel which contained a good replica of the source, and the array channel which was the signal derived from the upward-looking beam. Both channels had been digitized at a 48 kHz rate. The main interest in the present study was in the variability in volume scattering strength in small frequency bands. The 1800 m detonation depth of the source produced a bubble period of about

3 msec and a total duration for the source of approximately 10 msec. Thus it was decided to analyze the data in 93.8 Hz bands using a 512 point FFT.

PROCESSING METHOD

The spectrum of the source for each event was determined as follows: A 512 point FFT was calculated for both the source signal and of a sample of noise immediately preceding the source wavelet. The source spectrum was then computed by subtracting the spectrum of the noise from the spectrum of the signal. Figure 2 shows a typical replica of the source for one event and Figure 3 shows the spectrum for that event which was used in this analysis.

The analysis of the array signal was handled in a similar fashion. Starting with the surface arrival, the array signal was divided into blocks of 512 points. Each successive block was displaced from the previous block by 256 points, so there was a 256 point overlap for successive blocks. A 512 point noise sample from the array was transformed and the resulting spectrum was subtracted from that computed for each of these blocks. This process produced a matrix of 256 columns of frequency information and a variable number of rows (typically about 200) of depth information. For each event, each row of the matrix was corrected for the spectrum measured for the source for that same event and for frequency-dependent absorption and $1/r^{*2}$ spreading losses. The output for each event was one such matrix. Figure 4 shows a typical signal from the array channel, and Figure 5 shows a contour of the final output: depth vs frequency with contours

of scattering strength. In addition, a subset of the matrix was computed to simulate the results of the original processing as closely as possible: 1/6 octave bands were formed over the frequency range 1.6 kHz to 16 kHz, a Hanning smoothing was applied, and the results were contoured and plotted. Figure 6 is an example of that output.

In the final stage of the processing, the matrices representing the nine events were combined to produce final matrices containing: a) the average level for each cell, b) the 1/6 octave data over the limited frequency range, and c) the percent deviation for each cell. These data are displayed in Figures 7, 8, and 9, respectively. The average scattering strength levels were computed as follows: each cell of the output matrix for every event was summed linearly and the result divided by the number of events. In an analogous fashion, the unbiased standard deviation for each cell was computed on the linear (as opposed to dB) data. The percent deviation in each cell was determined by dividing the unbiased standard deviation by the average level and multiplying by 100.

It should be noted that, except for the 1/6 octave data, the data itself has not been smoothed. However, most of the contour diagrams have been smoothed during the plotting process. It should also be noted that the 1/6 octave data are plotted on a logarithmic frequency scale whereas the rest of the data is plotted on a linear frequency scale.

LIMITATIONS OF METHOD

Implicit in the above processing method was the assumption that the frequency responses of the array channel and the single hydrophone channel were identical. It should also be noted that the data have not been corrected for the gain differences between the array channel and that of the single hydrophone. Instead, the scattering strength levels have been arbitrarily shifted to give approximate agreement with those reported in Doult (1977). This shifting of levels has no effect on the percent deviation matrix.

The original analog data had been passed through anti-aliasing filters before being digitized. These filters were 3 dB down at 17 kHz and 5 dB down at 24 kHz (Stockhausen 1973). In addition, the source levels were low at the higher frequencies (Figure 3). Thus, even though the data is displayed out to 24 kHz, at the present stage in the analysis great confidence should not be placed in results much above 16 kHz since the signal levels were low.

An additional complication arises from the fact that the beamwidth of the array is a function of frequency. At the low frequency end of the present analysis the array has very little directivity; at the high end the grating lobes discussed by Stockhausen (1973) become a severe problem.

DISCUSSION OF RESULTS

A fact which was not appreciated until near the end of this analysis was that this site was bottom-limited, i.e. the events were terminated by the arrival of the bottom reflection and not that of the surface reflection. This analysis thus portrays the scattering from about 400 meters depth to 1200 meters depth. Another fact which should be noted is that many of the contour plots show anomalous data near the maximum depth. This is an artifact of the processing - some of the early, overloaded portion of the signal was included in the analysis. Furthermore, the contour plots show another anomalous, depth-independent region between 20 and 21 kHz. This is almost certainly a processing artifact - possibly due to an especially low signal-to-noise ratio in that region.

Figure 5, an unsmoothed plot of scattering strength for event 17, is particularly interesting because it shows many discrete areas which appear as dark spots because of the densely packed contours. At first it seemed that in the 2 - 16 kHz frequency range these represented either discrete resonant scatterers or clusters of resonant scatters. However, closer inspection reveals that many, if not all, of them represent "holes" and not peaks in scattering strength. The holes would be an artifact of the processing technique. At higher frequencies the data show horizontal (frequency independent) bands at certain discrete depths. It is not known at present whether these are in fact due to non-resonant scatterers or whether they are again an artifact of low signal levels and/or grating lobes at the higher frequencies. It seems most probable, however, that they are an

artifact. Figure 6 is a plot of the same event processed in a manner similar to the original analysis (compare to Figure 10a taken from that report). From this comparison it can be seen that the original $1/6$ octave analysis and the present FFT processing method produce similar results.

As explained previously, nine events were combined to produce average scattering strength levels. Figure 7 shows the results from this study, and the results processed in a manner similar to the original report (Figure 8) can be compared to a plot from the original report (Figure 10b). Figure 7 shows that the decrease in scattering strength with decreasing frequency observed in the original report continues until it reaches a minimum of about -105 dB near 1 kHz. It then appears to increase at still lower frequencies. However, since these lower frequencies are below the original design specification of the instrument, further work would be necessary to verify this observation. At higher frequencies, excluding the anomalous region near 20 kHz, the scattering levels gradually rise from -80 dB near 16 kHz to -70 dB near 24 kHz.

In addition to the averages, unbiased standard deviations were also computed and converted into percent deviations (see appendix B). These values were converted into dB and plotted in Figure 9. Forty dB thus corresponds to a standard deviation equal to the mean. Each six dB lower level corresponds to a standard deviation smaller by a factor of two. The values range from a maximum of 49 dB to a minimum of 24 dB. As can be seen from the smoothed contour plot of these data (Figure 9), the

highest values - the largest deviations - occur at the lower frequencies and again at the higher frequencies. Over the depth range covered by this analysis, the deviation is roughly independent of depth. Values of about 36 dB occupy the region from three kHz to eight kHz. This confirms the qualitative conclusions reached in the original report regarding the stability of scattering regions I and II (300 m - 1000 m and 4 kHz to 8 kHz).

CONCLUSIONS

At this site, the variability of scattering strength levels over a period of one hour in a broad region from 400 meters to 1000 meters in depth and from 4 kHz to 16 kHz in frequency was shown to be relatively depth and frequency independent. The standard deviation at the lower frequency range was approximately four dB less than the mean scattering strength level and at the upper frequency was slightly greater than the mean scattering strength level.

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APPENDIX A

The nine events used in this report were from Maria Paolina cruise 1973-6 events 8,9,11,12,13,14,15,16,17.

event	time	nominal array depth (m)	source depth (m)	water depth (fms)
008	2311 52	1200	1800	1370
009	2338 15	1200	1820	1370
011	2351 26	1200	1890	1370
012	2357 15	1200	1880	1370
013	0003 21	1200	1855	1370
014	0008 12	1200	1855	1370
015	0012 58	1200	1830	1370
016		1200	1805	
017	0023 26	1200	1830	1375
018				

APPENDIX B

Formulas

$$\text{avg} = \frac{1}{N} * \sum_{i=1}^N (\text{Event } i)$$

$$\text{dev} = \frac{1}{N-1} * \sum_{i=1}^N (\text{Event } i)^2 - N * \text{avg}^2$$

$$\text{percent dev} = 20 * \log_{10} (100 * \text{dev} / \text{avg})$$

$$= 40 + \log_{10} (\text{dev} / \text{avg})$$

REFERENCES

1. DOUTT, J.A. Broadband measurements of volume scattering strength in the Mediterranean, SACLANTCEN Report SR-17. La Spezia, Italy, SACLANT ASW Research Centre, 1977.
2. STOCKHAUSEN, J.H., and FIGOLI, A. An upward-looking bistatic research system for measuring deep scattering layers in the ocean, SACLANTCEN TR-225. La Spezia, Italy, SACLANT ASW Research Centre, 1973. [AD 764 395]

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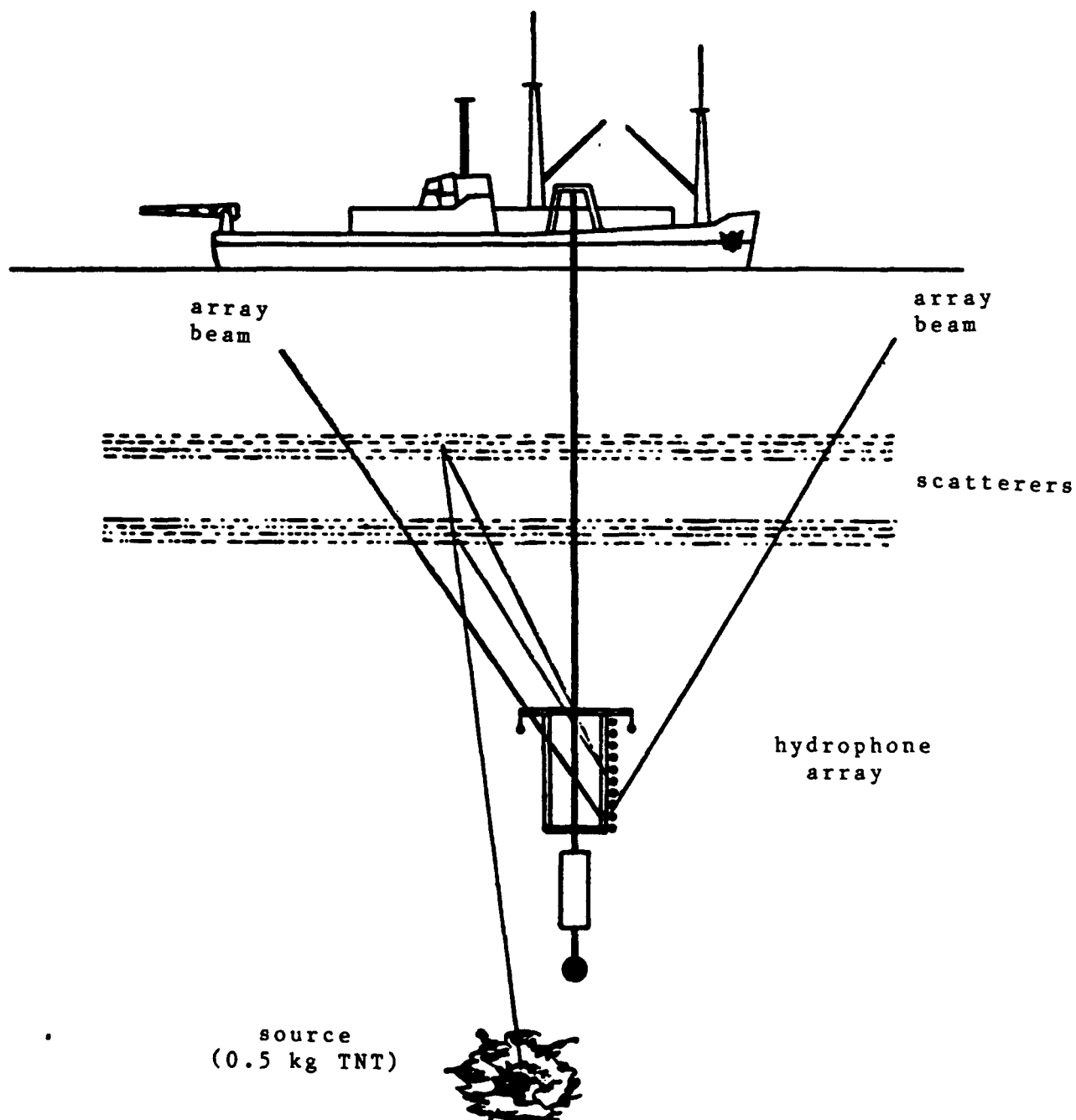


FIG. 1 EXPERIMENTAL SET-UP

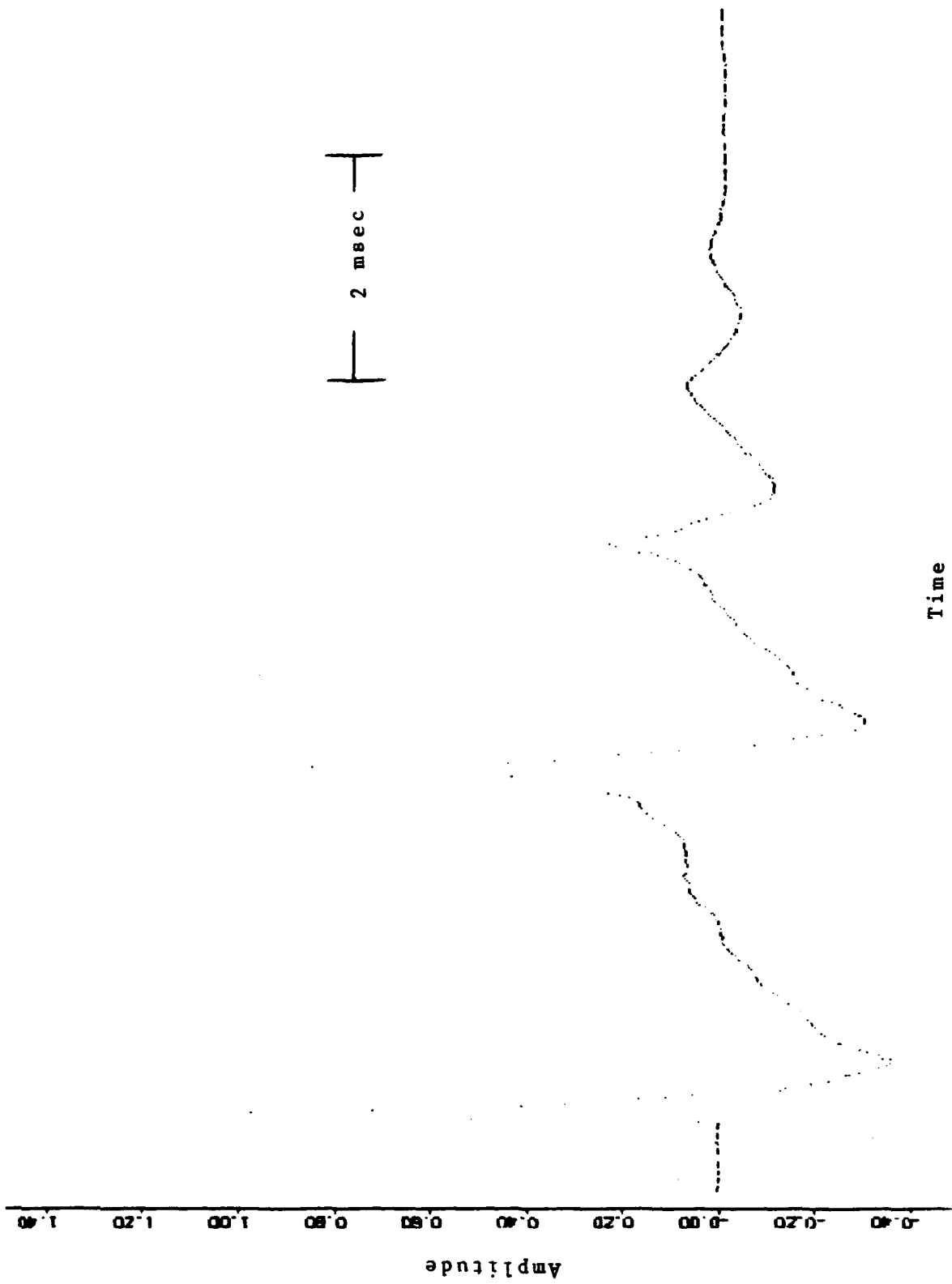


FIGURE 2. Replica of typical source (event 17).

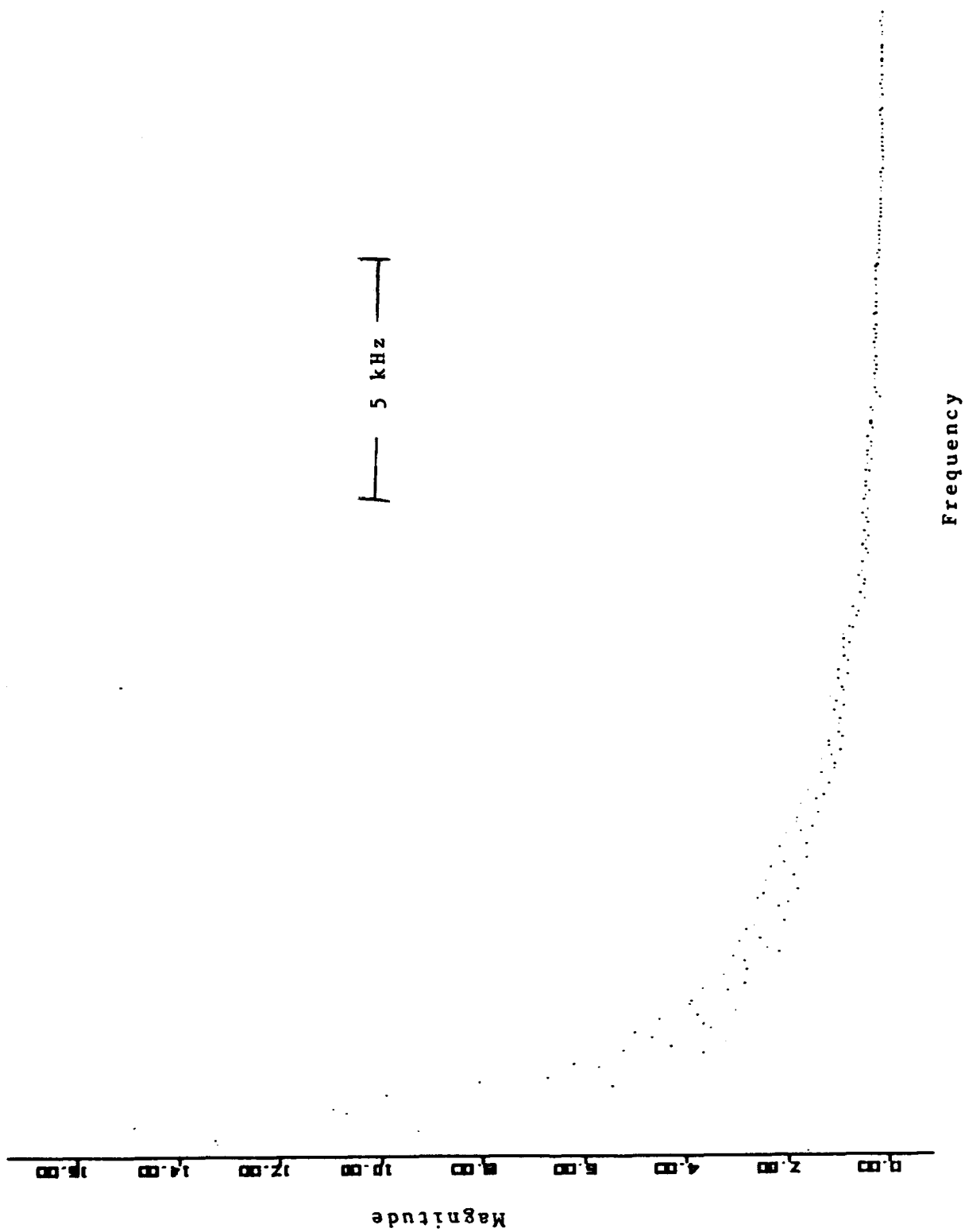


FIGURE 3. Spectrum of signal in Figure 2.

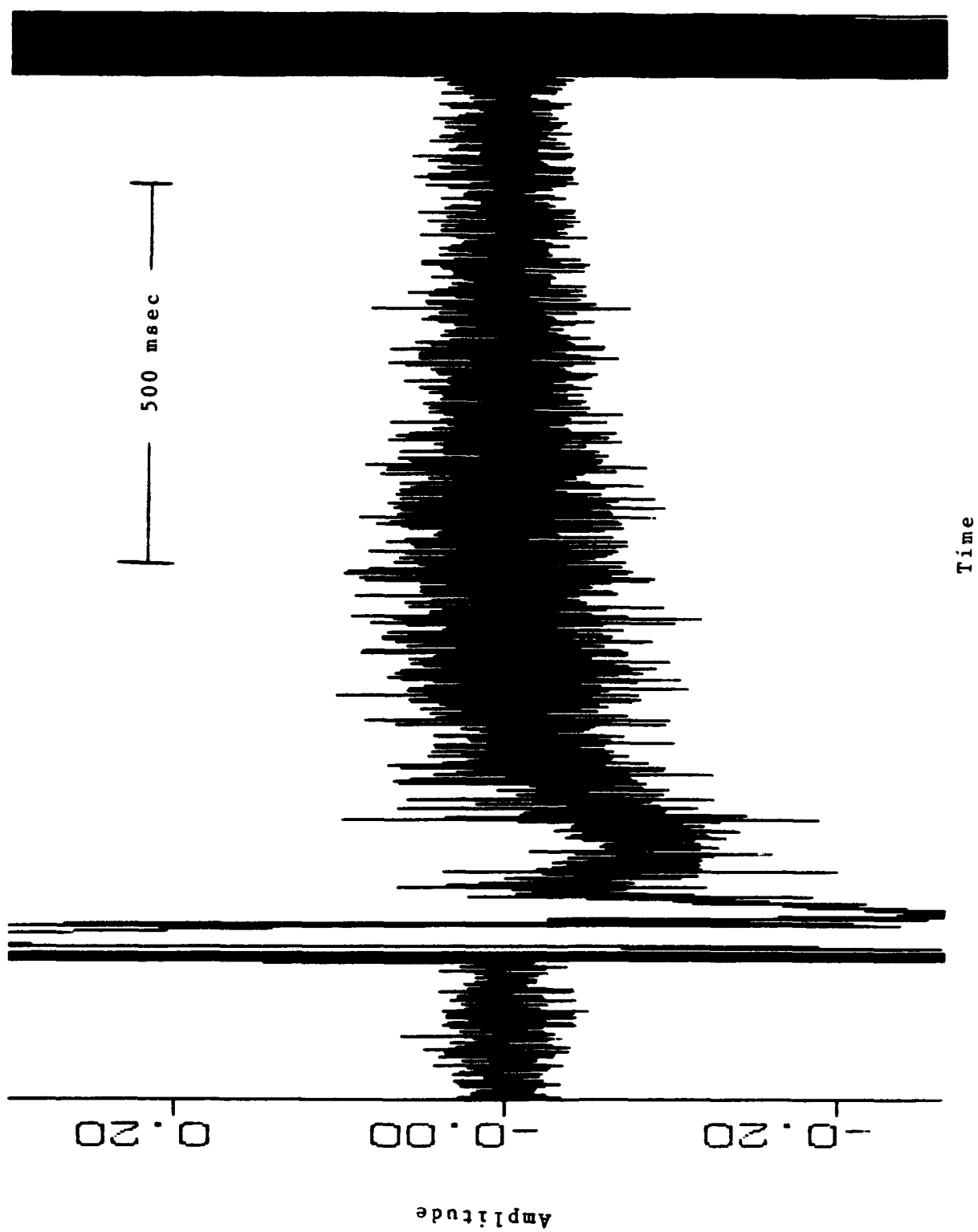


FIGURE 4. Typical signal from array (event 17).

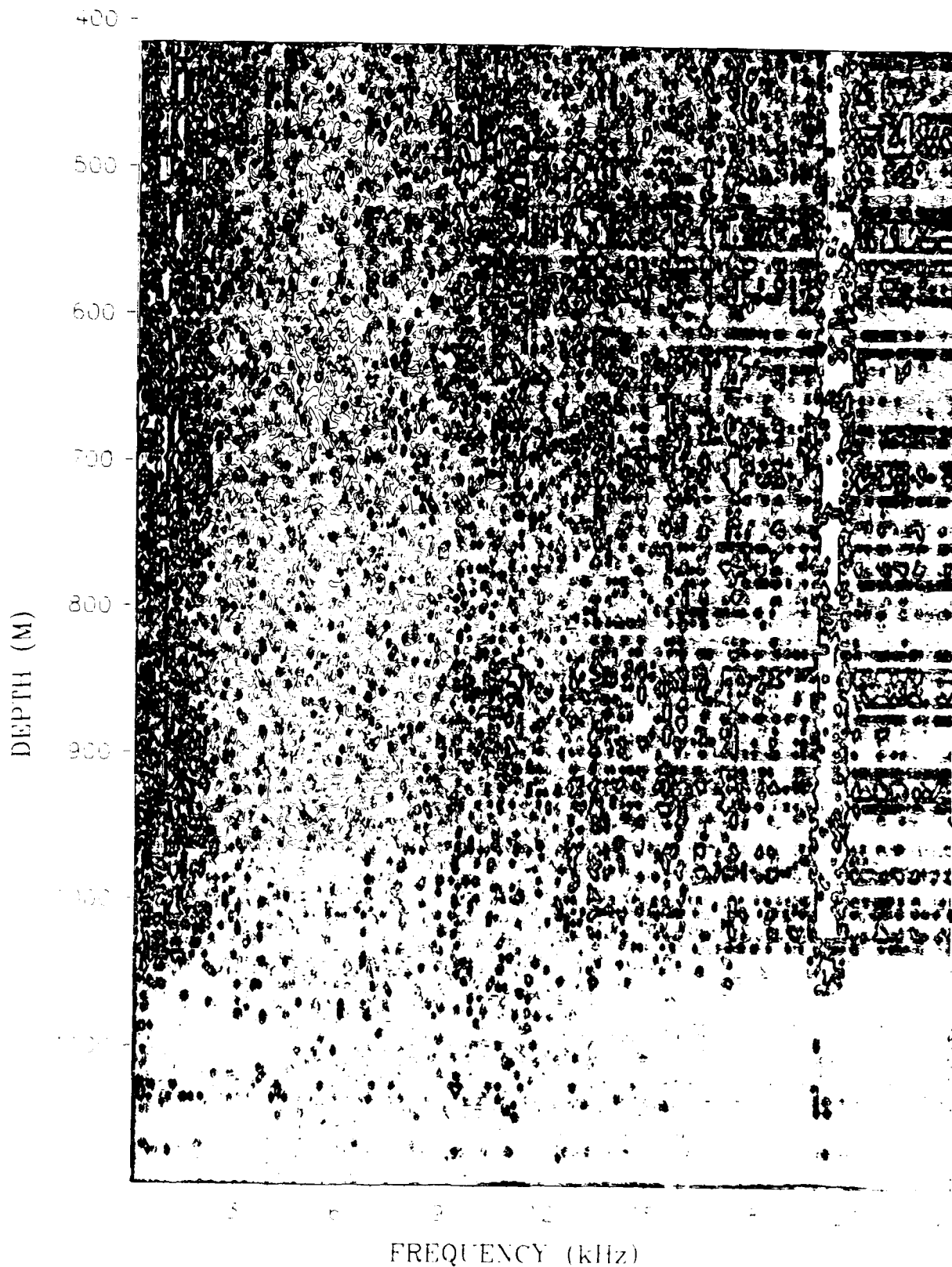


FIGURE 5. Scattering strength contour diagram for event 17. Linear depth and frequency (0.1 - 24 kHz) scales. Contour interval 5 dB. No smoothing.

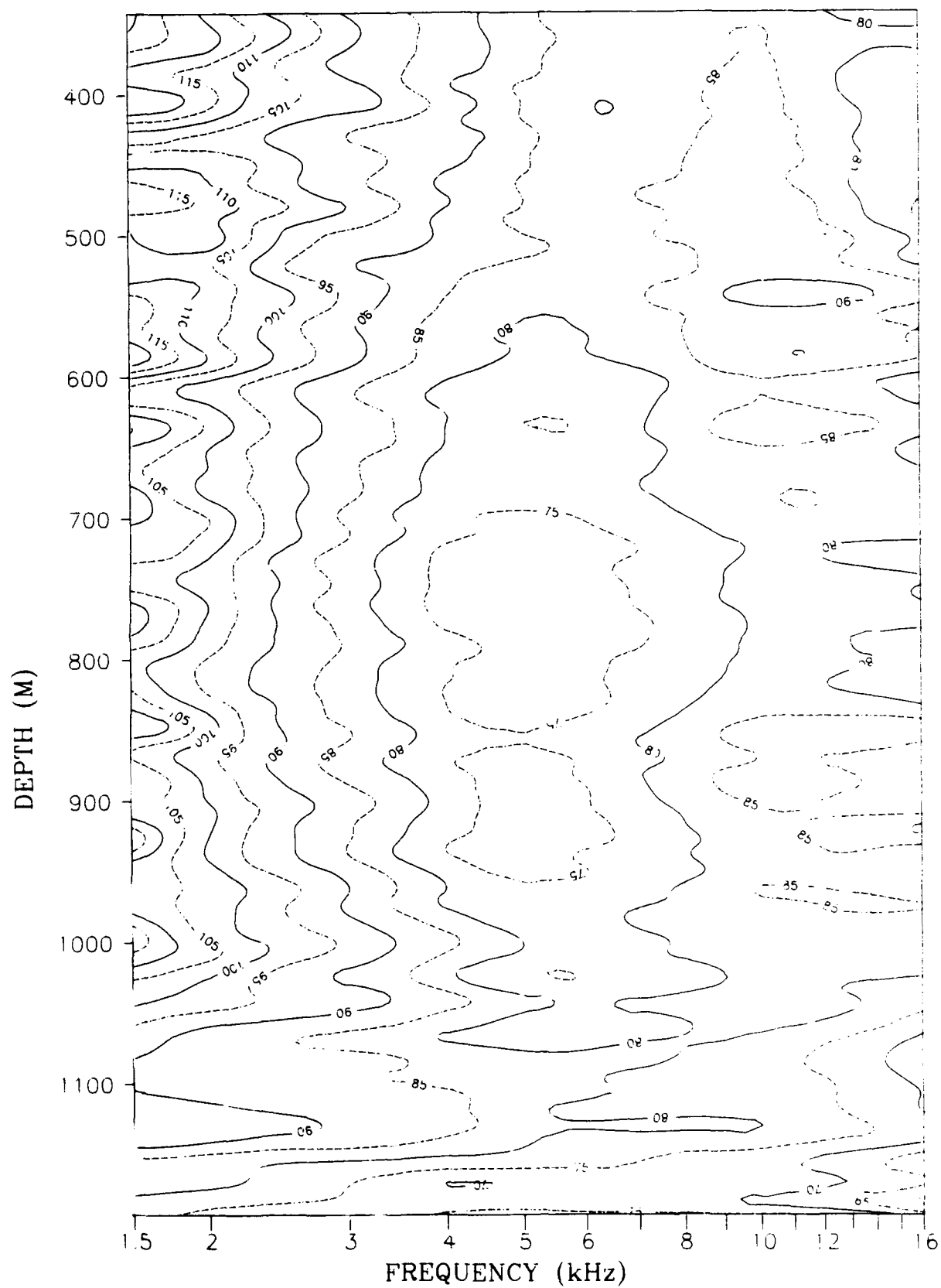


FIGURE 6. 1/6 octave scattering strength diagram for event 17. Linear depth and logarithmic frequency (1.6 - 16 kHz) scales. Contour interval 5 dB.

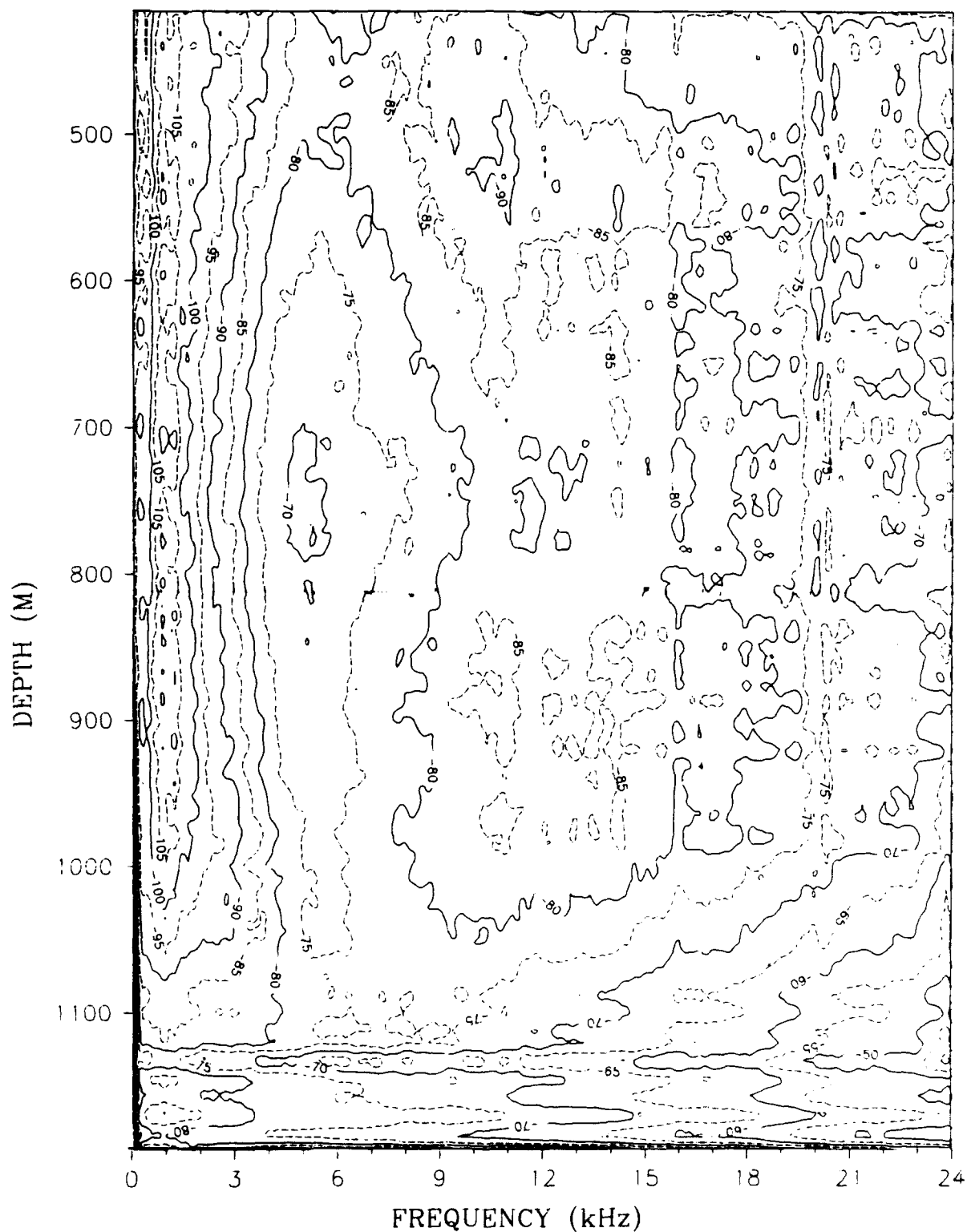


FIGURE 7. Scattering strength contour diagram for average of all events. Linear depth and frequency (0.1 - 24 kHz) scales. Contour interval 5 dB.

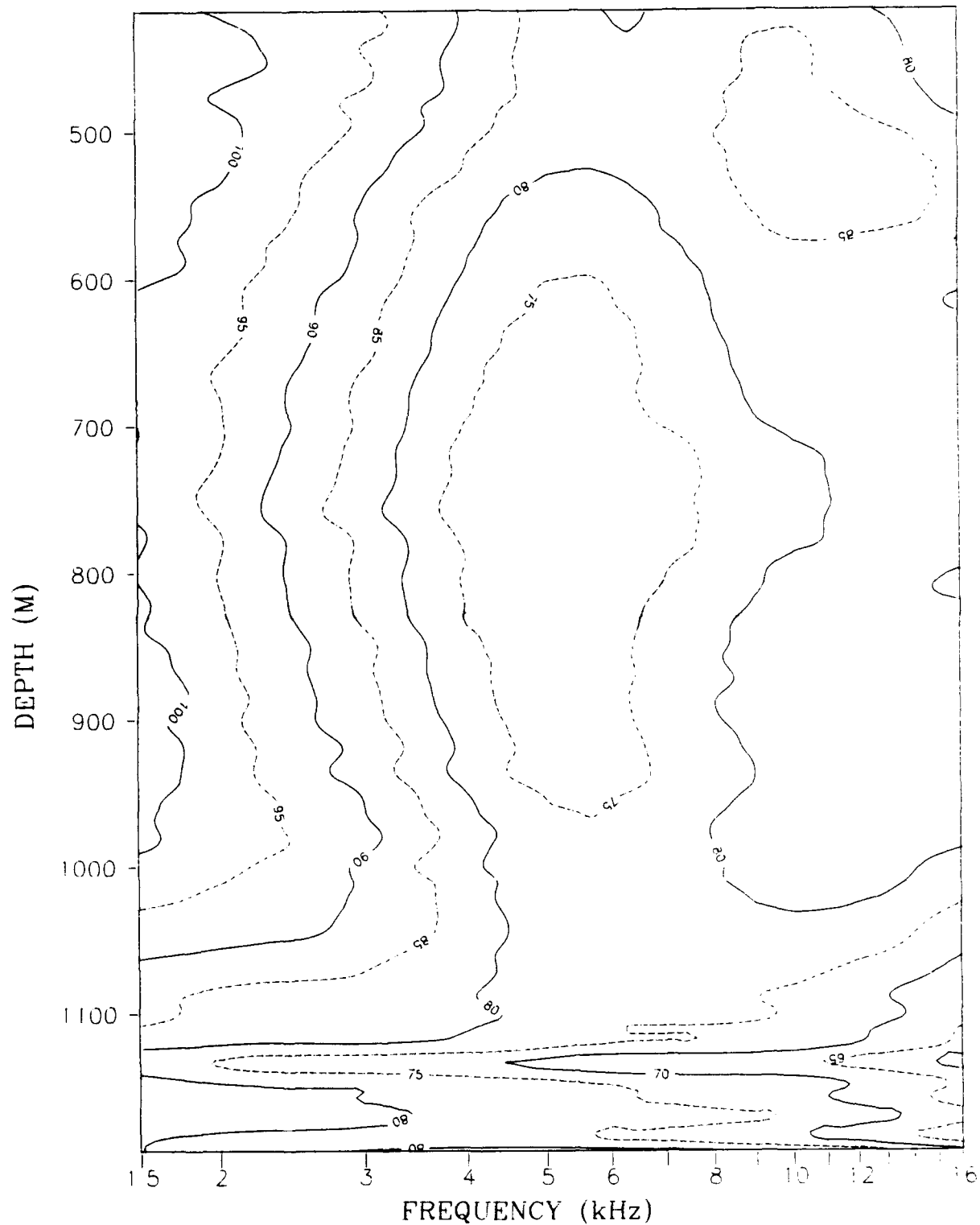


FIGURE 8. 1/6 octave scattering strength contour diagram for average of all events. Linear depth and logarithmic frequency (1.6 - 16 kHz) scales. Contour interval 5 dB.

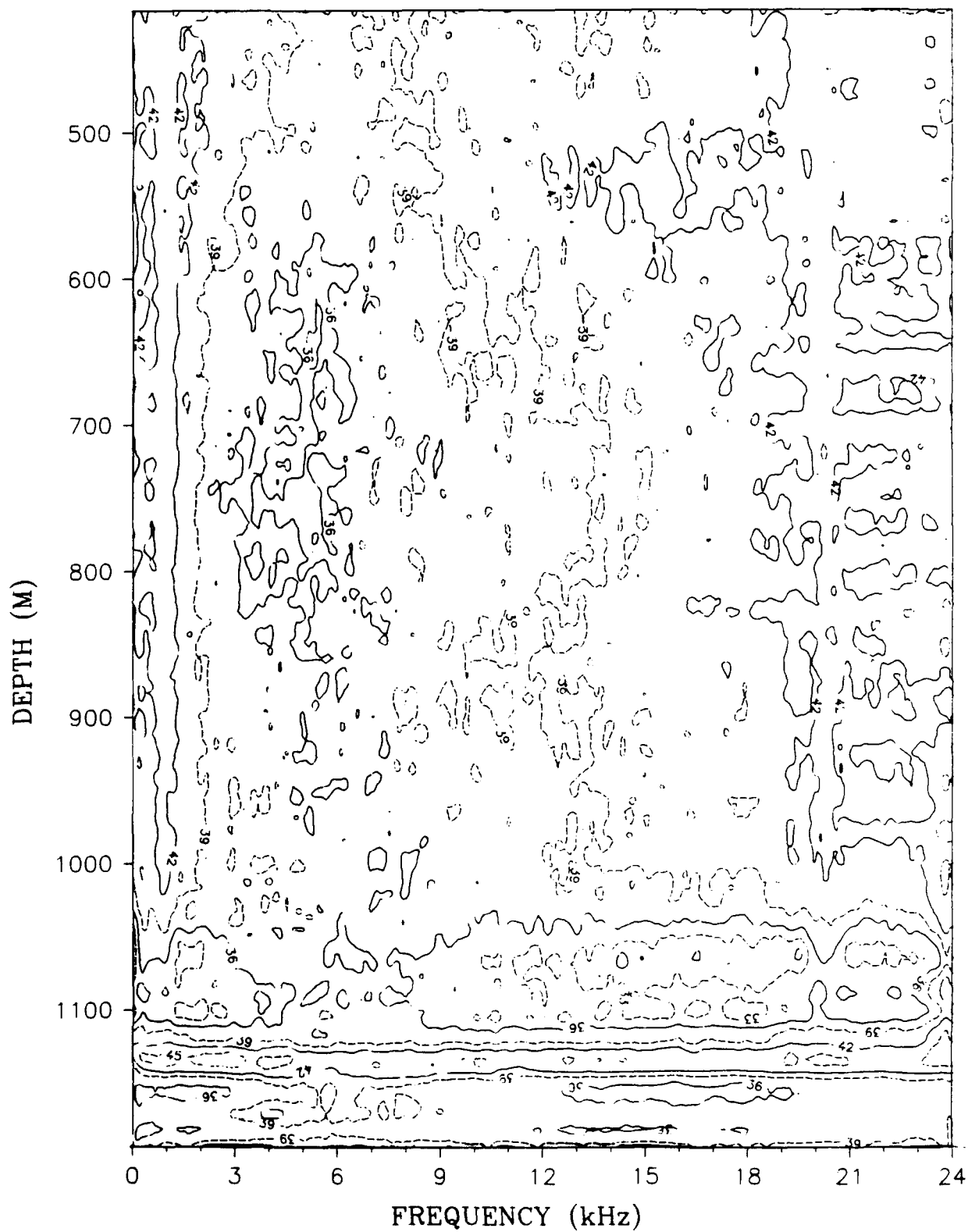
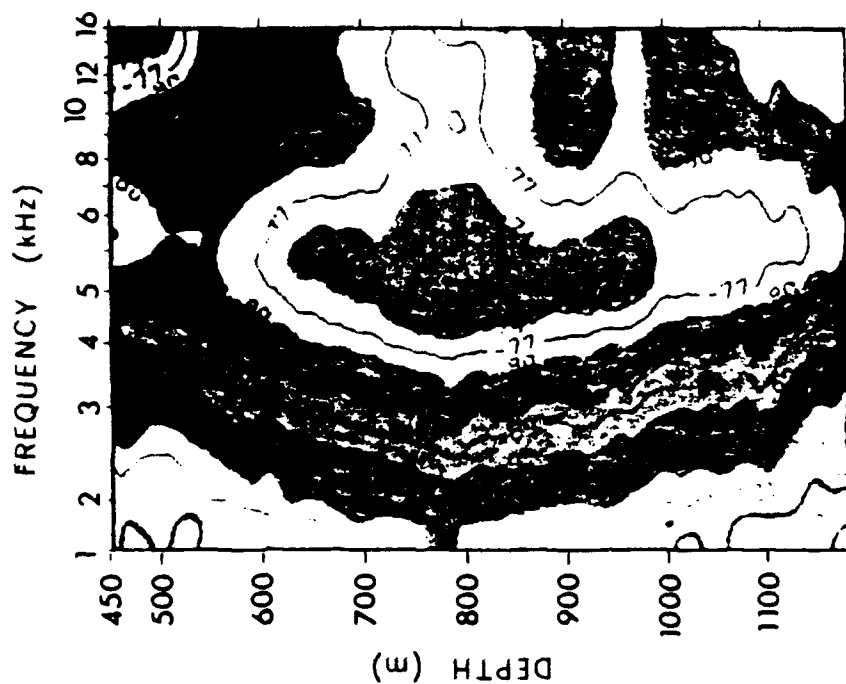
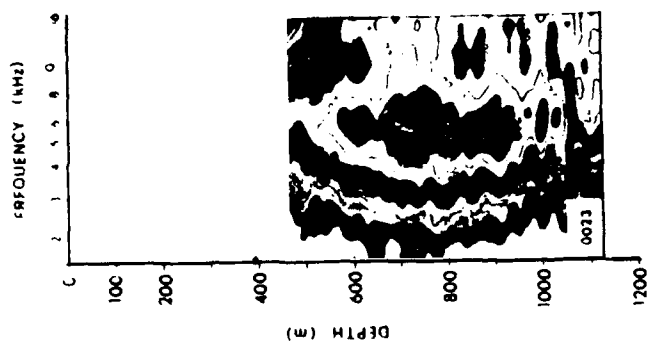


FIGURE 9. Percent deviation contour diagram for average of all events. Linear depth and frequency (0.1 - 24 kHz) scales. Contour interval 3 dB.



(a)



(b)

FIGURE 10. Scattering strength contour diagrams from previous report (DOUTT 1977)
 (a) Event #17
 (b) Average of nine events

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